

On-animal sensors for the detection of key behaviours to enable refined management

Mark Trotter



BE WHAT **YOU** WANT TO BE
[cqu.edu.au](https://www.cqu.edu.au)

Mud-map – what I'll talk about

- Introduction
- What is the industry in which we work?
- What sensors systems are being developed and why?
- Algorithm development for behavioural monitoring
- What is the future look like?

Introduction

- Who is Mark Trotter?
- I grew up on a dairy farm on the Mid-North Coast of New South Wales (say about half way between Sydney and Brisbane)
- Family owned Jersey Stud (now sold)
- Spent a lot of time on my extended families beef operation as well
- Had a small Devon cattle stud
- Bred and campdrafted Australian Stock Horses



Introduction

- Went to University of New England (in Aus not the US)
- Bachelor of Rural Science
- First job: Agribusiness Analyst in a bank
- PhD in Pasture Agronomy (at UNE)
- Then: Precision Agriculture Research Group at UNE (worked there for ~10 years)
- Focussed on Precision Livestock and Pastures
- Now a Professor at CQUniversity (Rockhampton Queensland)



The team

- Dr Thomas Williams
- Dr Cara Wilson
- Dr Patricia Colusso
- Dr Diogo Costa
- Dr Jaime Manning
- Dr Elle Fogarty
- Prof. Dave Swain
- Dr Kym Patison
- Dr Anita Chang
- Dr Robin Dobos (NSW DPI)
- Dr Jaime Barwick (UNE)
- Dr Alvaro Garcia (OSU)
- Prof Jim Kinder (OSU)
- Prof Derek Bailey (NMSU)
- Prof Ryan Reuter (OkSU)
- Dr Luis Moraes

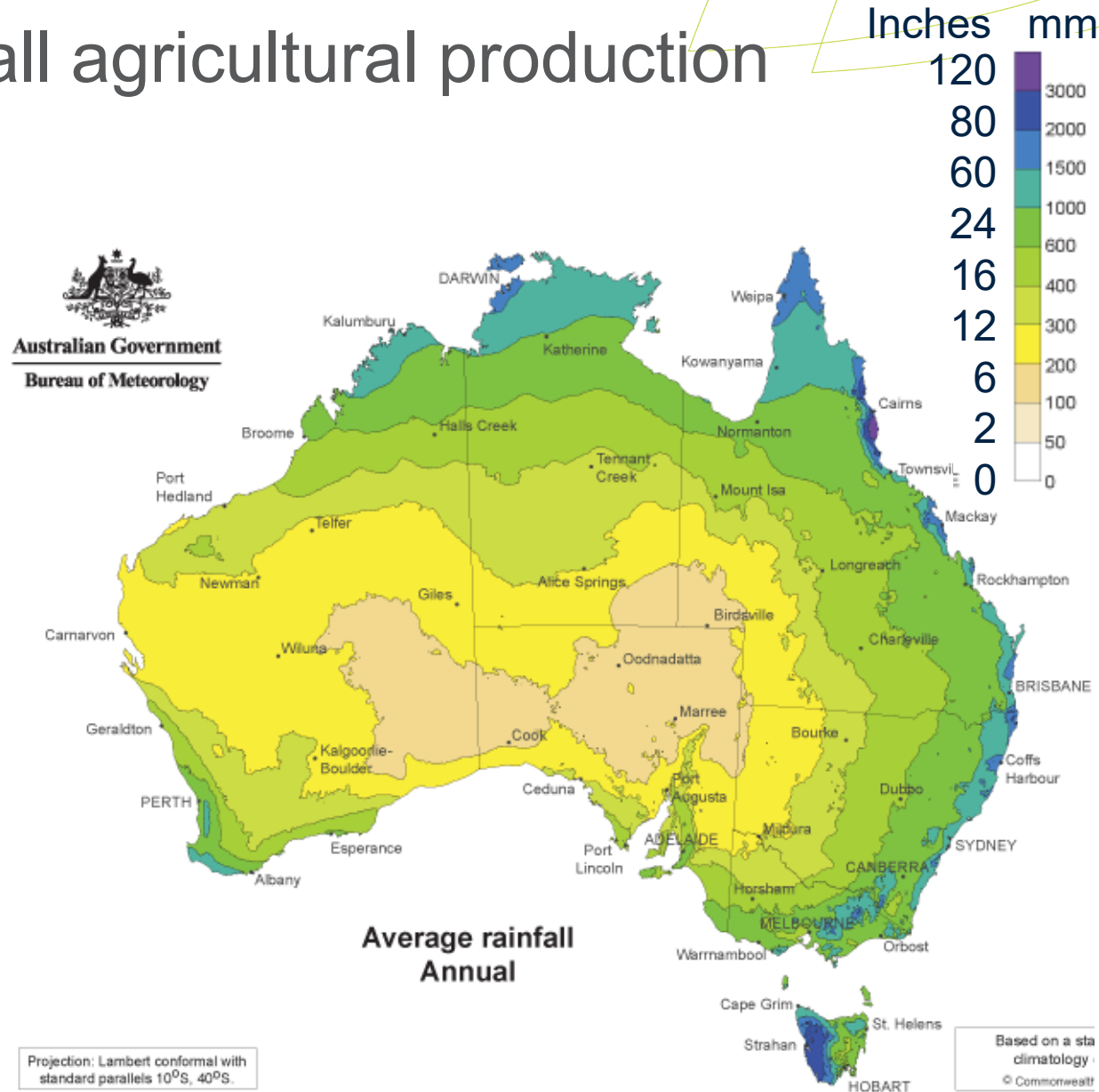


A quick introduction to the grazing industries in Australia



Rainfall drives all agricultural production

- Seasonality is key
- South = wet winter, dry summer
- North = wet summer, dry winter
- Everywhere = unreliable



The grazing industries - Dairy

- ~5,700 dairy farms
- Average herd = 262 cows
- ~ 60–65% of feed is pasture (TMR is the exception)
- 65% Holstein



Sheep

- 40,000 sheep farms
- ~70 m sheep (in 1970 it was 180m)
- ~75% Merino
- 350 million Kg of greasy wool
- Worlds biggest exporter of lamb/sheep meat

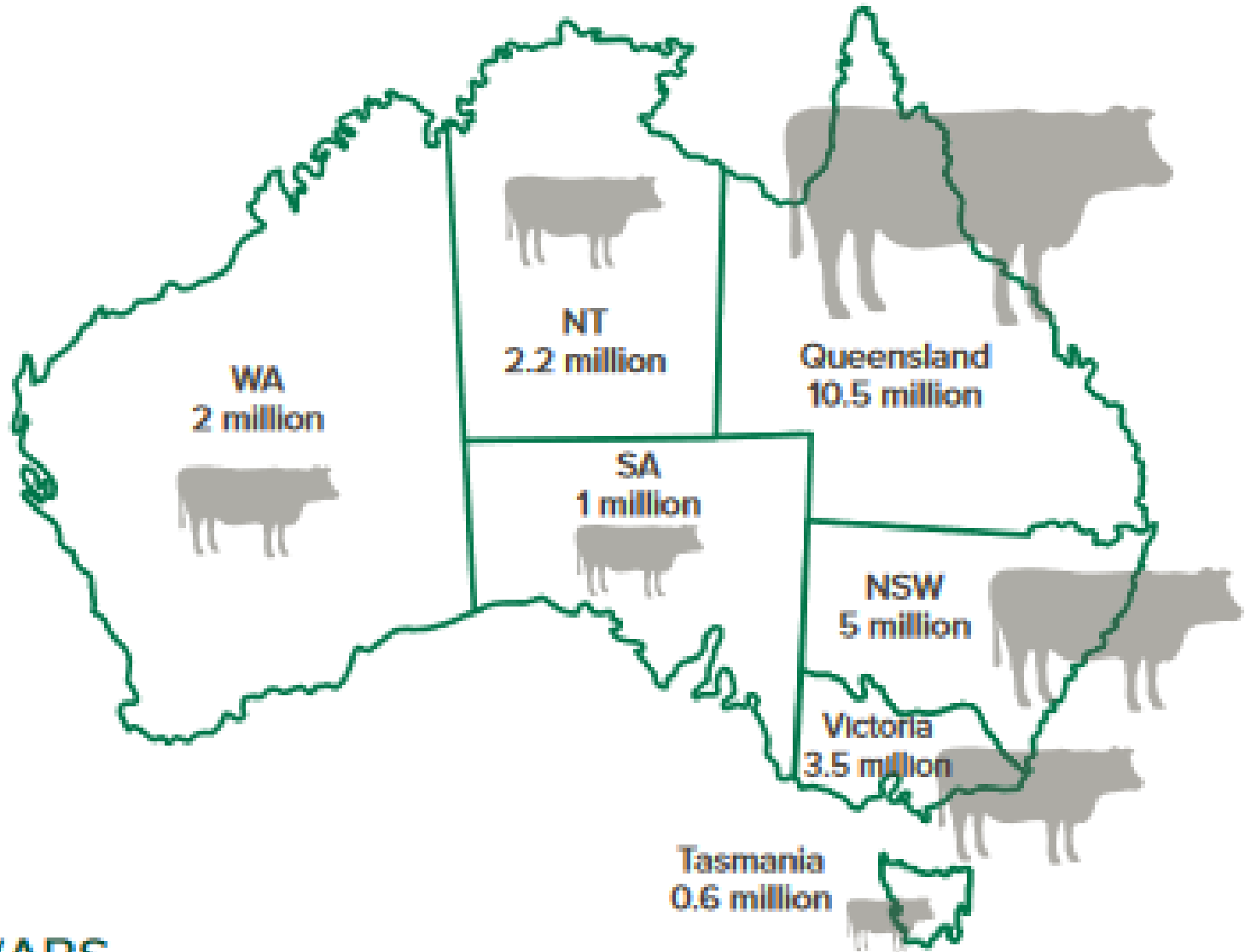


Beef industry in Australia

- 47,000 farms with beef cattle
- 25 million head of cattle
- Breeding herd of 11m
- Gross value of \$13 billion (20% of farm GDP)
- 40% of cattle slaughtered are grain finished
- 7th in world for production
- 3rd in world for export

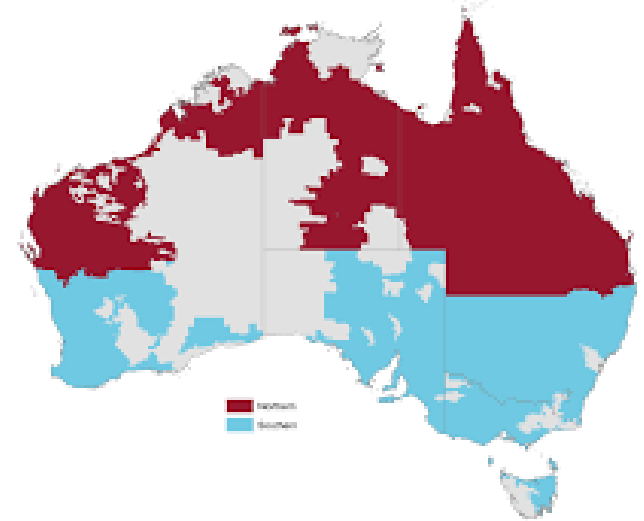


Where are all the cattle?



The Northern Beef Industry

- Large areas
- Low productivity
- *Bos indicus* (*Brahman*) dominate
- Some still wild harvest
- Lower quality beef
- Live export important
- Labour is the key cost
- Transport issues
- Low use of genetic improvement

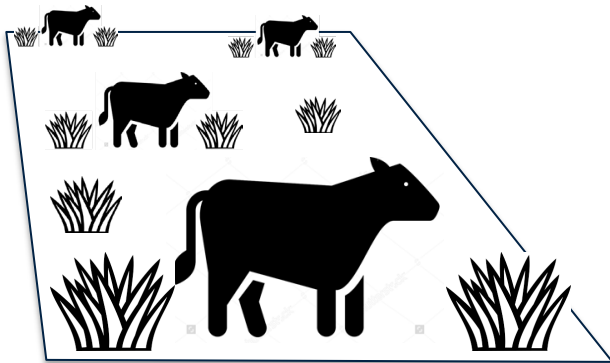


= big opportunities for improvements

Digital technologies in the rangelands...

What happens at the moment?

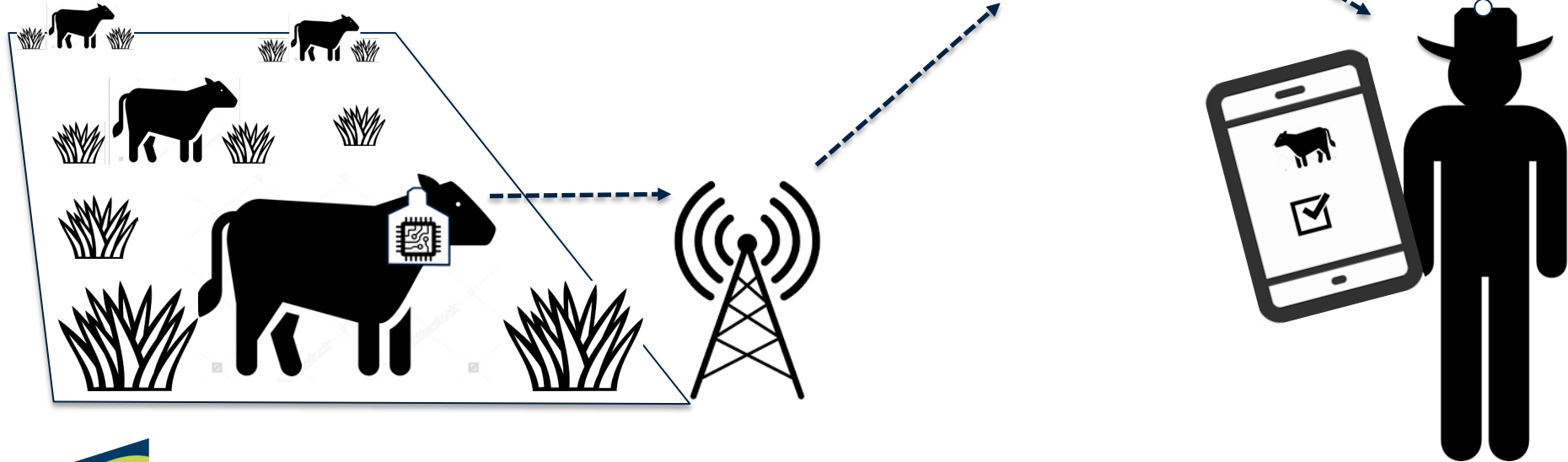
- Producers periodically check on livestock, pasture and infrastructure
- Regularity of observation is limited by time and cost



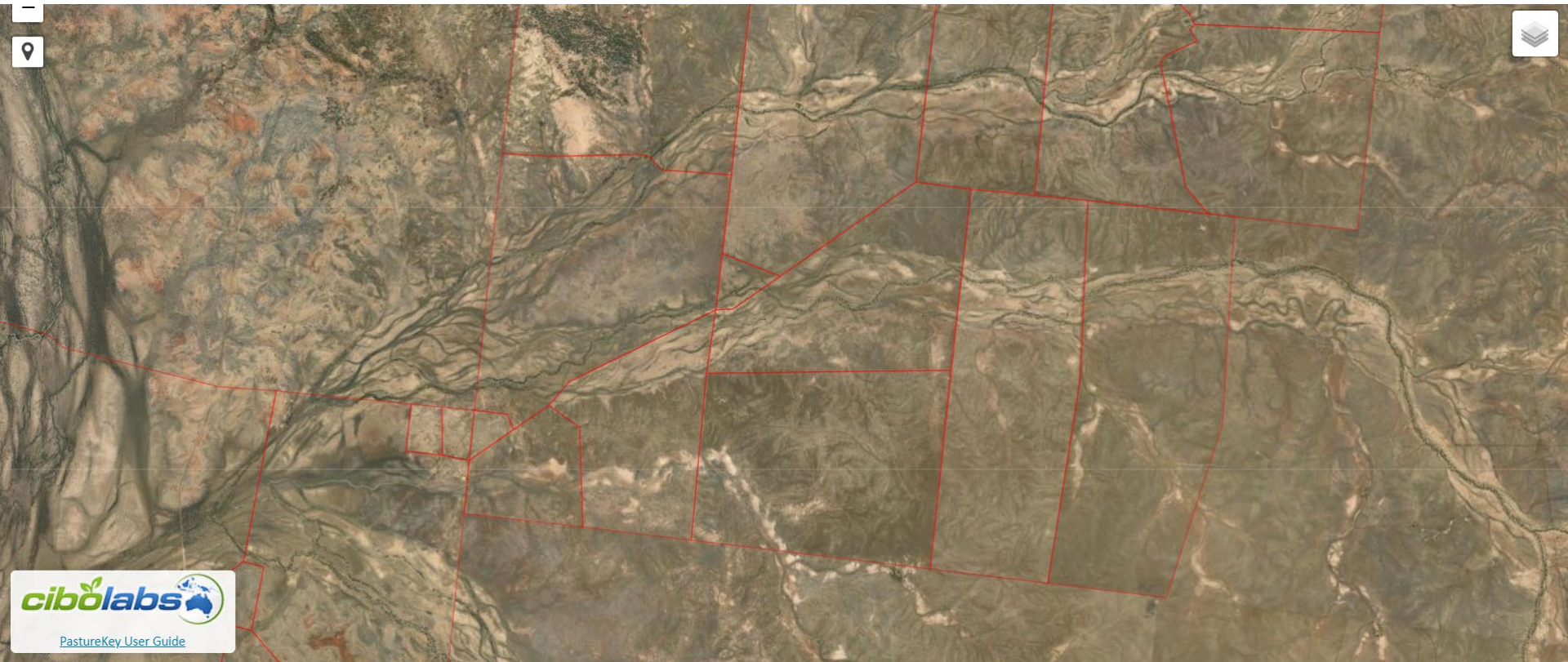
Distance = a long way

What is emerging?

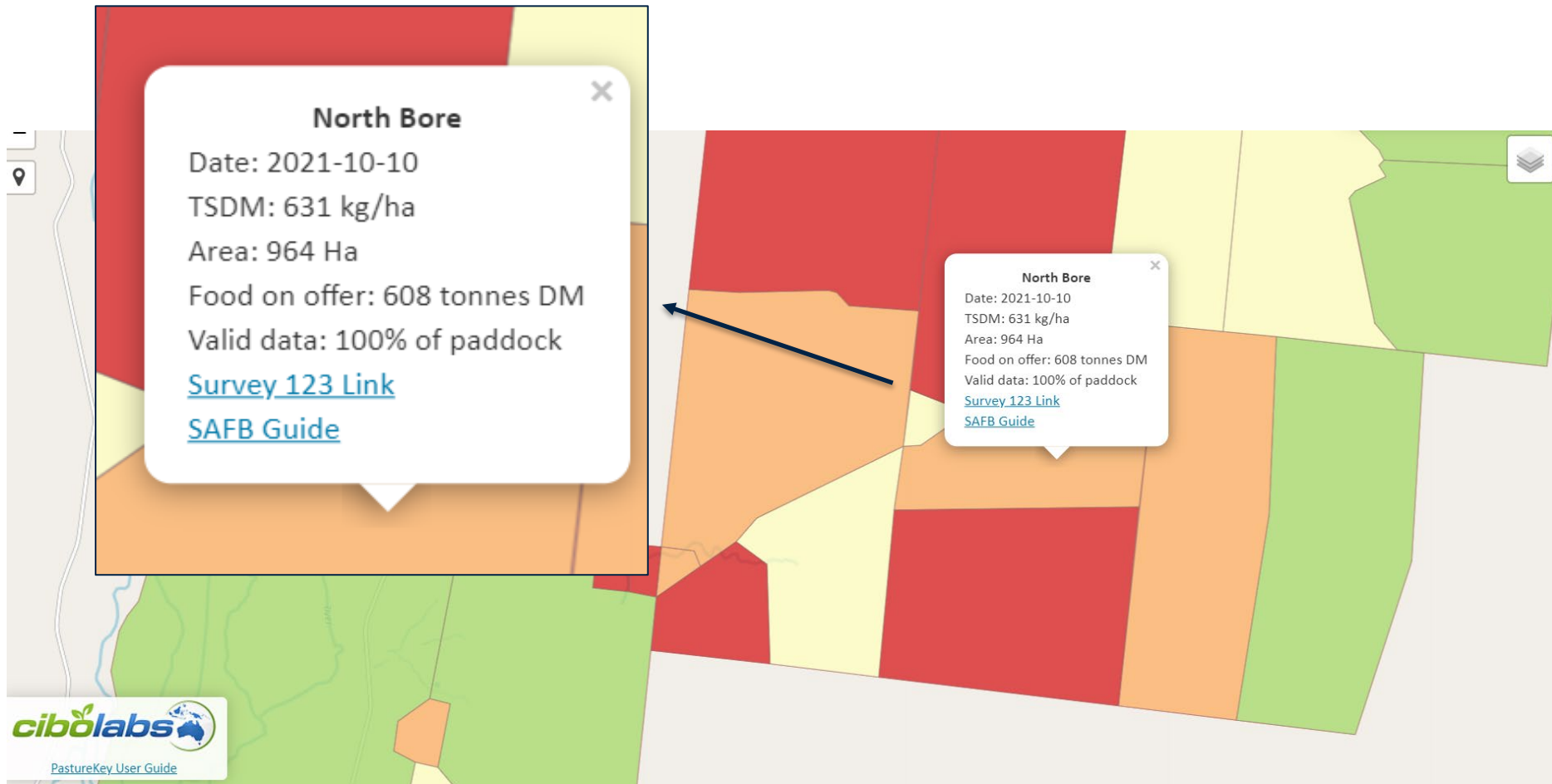
- Sensor and control technologies that enable:
 - Objective data collection
 - Precise management



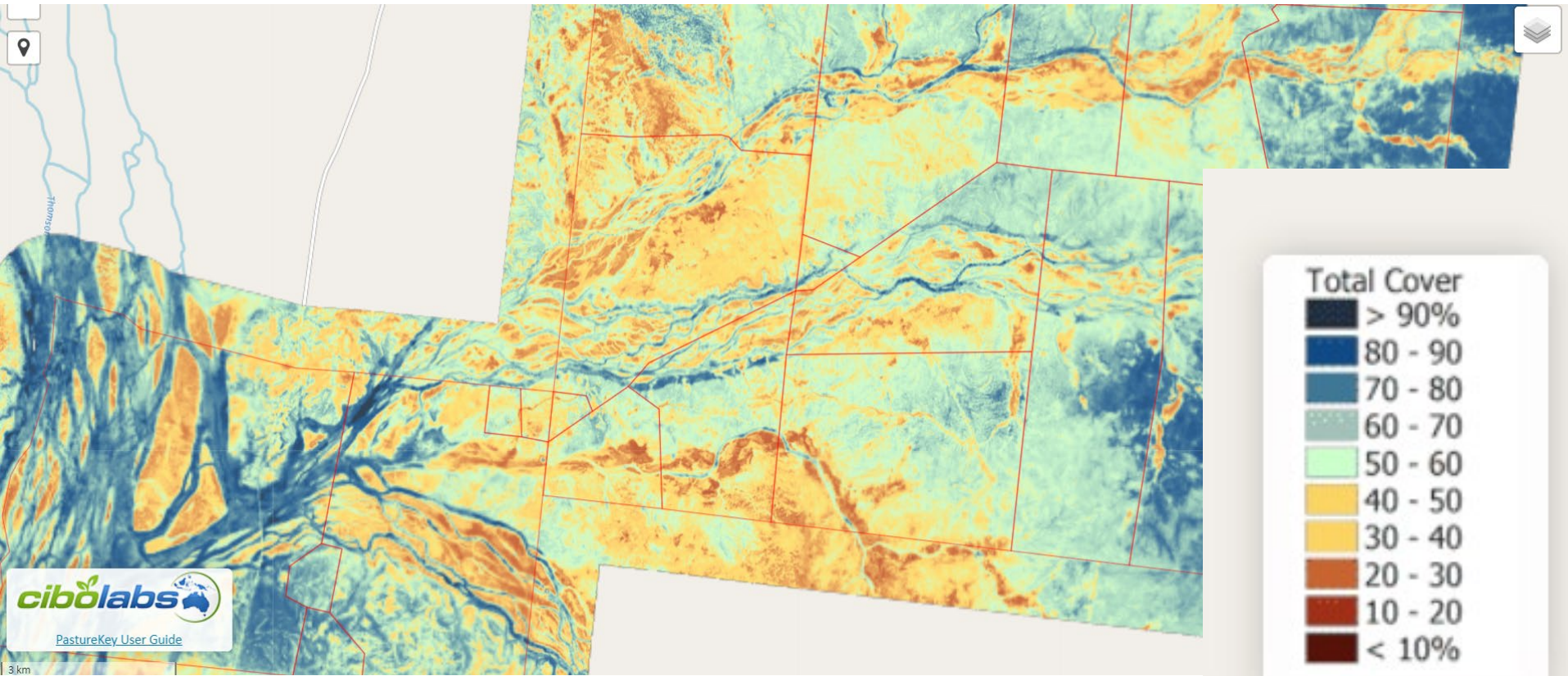
Measuring productivity of pastures



Satellite based pasture estimates

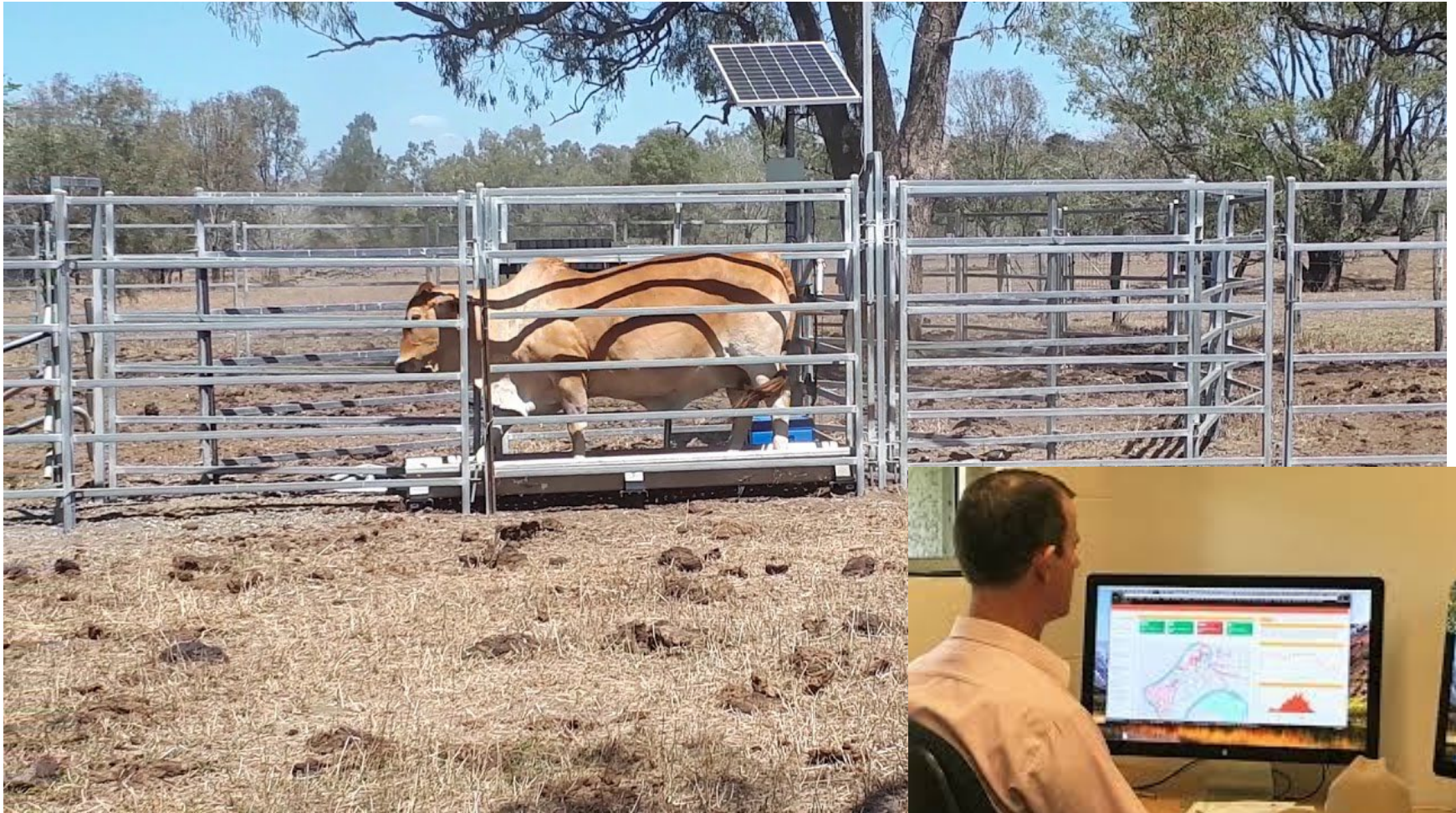


Objective measures of sustainability




Map contributors @ Cibolabs

Measuring productivity of animals



Weekly data on liveweight change...




Property Choice:
CQIRP

Filtering Options:

Paddock Groups
 Whole Property
 Paddock






Males or Females
 All Cattle
 Males
 Females

Breeders or Growers
 All Cattle
 Breeders
 Growers



Language Options:
 English Español

Property Information

-  Overview
-  Carrying capacity
-  Forage budgeting
-  Animals
-  ALMS

Animals

Data level: Whole Property

Name: CQIRP

Total cattle: 11

Breeding cattle: 0

Growing cattle: 11

Average weight (kg): 467


Average breeder weight (kg): NA

Average grower weight (kg): 467

Last weight date: 23 07 2021

Select a paddock on the Property map to view paddock information

Property Map



Leaflet | © OpenStreetMap contributors

Animal Data

[Weekly ALMS Growth](#)
[Weekly ALMS Weights](#)
[Daily ALMS Access](#)
[Daily ALMS Weights](#)
[Today's ALMS Data](#)
[Table of Individual Data](#)
[Manage Cattle](#)
[Upload Cattle Data](#)

[Download as csv](#)

Show entries

Search:

RFID	Tag	Sex	Category	Paddock	Hours since last ALMS record	Last Average ALMS Weight (kg)	ALMS Weight Date
982 123516147146	no tag	Male	Growing	SW Pdk	15	822	2021-07-25
982 123735278220	17930	Female	Growing	SW Pdk	15	458	2021-07-25
982 123735278198	17931	Female	Growing	SW Pdk	15		2021-07-25
982 123735278225	17932	Female	Growing	SW Pdk	15	428	2021-07-25
951 000306004274	17933	Female	Growing	SW Pdk	15	414	2021-07-25
982 123735278192	17934	Female	Growing	SW Pdk	15		2021-07-25
982 123735278189	17935	Female	Growing	SW Pdk	15	405	2021-07-25
982 123735278204	17936	Female	Growing	SW Pdk	15	423	2021-07-25
982 123735278193	17937	Female	Growing	SW Pdk	15	417	2021-07-25

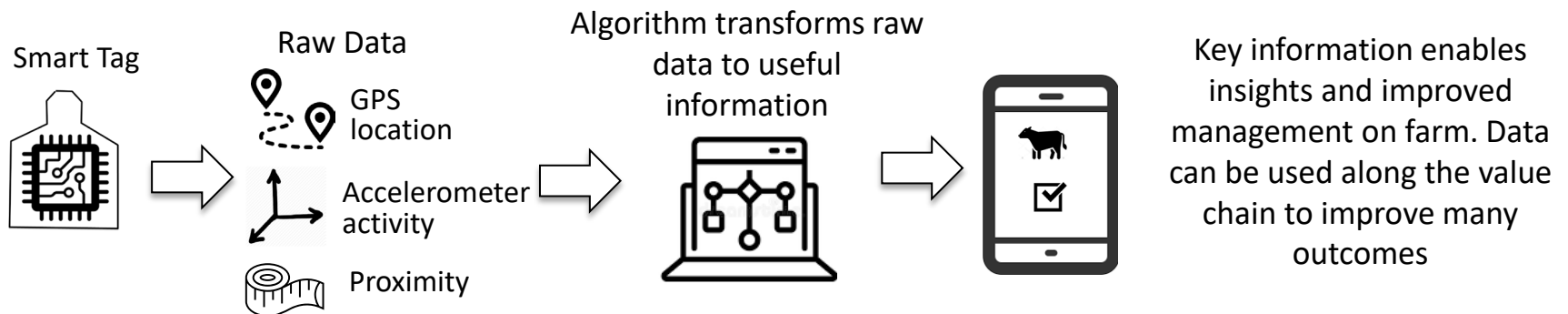
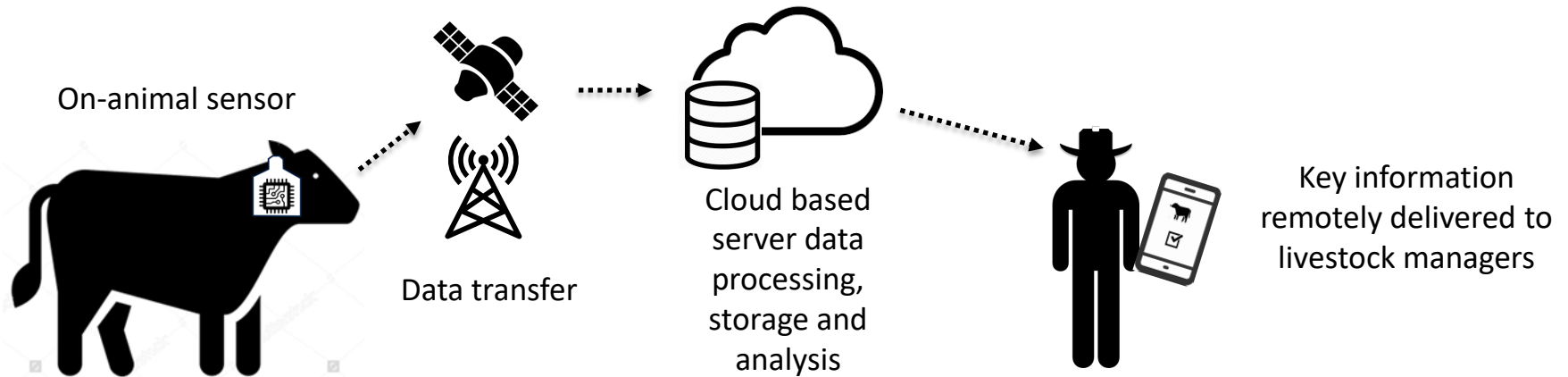
- Columns to show:
- RFID
 - Tag
 - Sex
 - Category
 - Paddock
 - Hours since last ALMS record
 - Last Average ALMS Weight (kg)
 - ALMS Weight Date
 - Last Crush Weight (kg)
 - Crush Weight Date
 - Breed
 - Colour
 - Brand
 - Horn status
 - Date of birth
 - Dam tag
 - Sire tag

On-animal sensors

- A device attached to the animal
- Provides key data on the individual animal
- Set to revolutionise the livestock industry (???)



How do they work?



A working example – Smart Paddock

SMART PADDOCK



Google

Imagery ©2021 CNES / Airbus, Maxar Technologies | Terms of Use | Report a map error

Belmont

31 Bluebell tags registered

Livestock List

Alerts **30**

TAG 01749 HAS TRIGGERED A GEOFENCE ALERT

geofence notified

My Id: | Tag Id: FEC23DFFFE2878CD

-23.234079, 150.3660564

07/03/2021 01:54am

TAG 01777 HAS TRIGGERED A GEOFENCE ALERT

geofence notified

My Id: | Tag Id: FEC23DFFFE23E626

-23.2373346, 150.3646582

03/03/2021 05:58am

TAG 01766 HAS TRIGGERED A GEOFENCE ALERT

geofence notified

My Id: | Tag Id: FEC23DFFFE285D20

-23.2340446, 150.3632913

26/02/2021 06:46pm

TAG 01781 HAS TRIGGERED A GEOFENCE ALERT

geofence notified

My Id: | Tag Id: FEC23DFFFE238E93

-23.2320696, 150.3596416

26/02/2021 04:23pm

TAG 01761 HAS TRIGGERED A DOWNED ANIMAL ALERT

downed animal notified

My Id: | Tag Id: FEC23DFFFE239015

-37.9417575, 145.064523

26/02/2021 04:20pm

TAG 01758 HAS TRIGGERED A GEOFENCE ALERT

geofence notified

My Id: | Tag Id: FEC23DFFFE23D0F5

-23.2318756, 150.3596401

26/02/2021 04:19pm

The big question...

How will the
industry get
value out of this
tech?

What do the producers want?

“If you had real-time location/behaviour/stock information on your livestock, how would you use it and what are the most important applications?”

Trotter, M., A. Cosby, J. Manning, M. Thomson, T. Trotter, P. Graz, E. Fogarty, A. Lobb, and A. Smart. 2018. **Demonstrating the value of animal location and behaviour data in the red meat value chain.** Meat and Livestock Australia Limited.

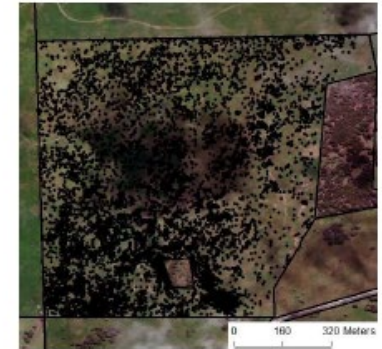


Application	All respondents (%) n= 60
Water related behaviour	53
Welfare monitoring	45
Mustering efficiency	42
Timing grazing rotations	40
Health alerts for critical injuries	38
Calving and lambing detection	35
Landscape utilisation	33
Pregnancy status	30
Disease detection	27
Refining supplementary feeding	25
Stock theft	25
Predation detection	20
Genetic matching (dam/offspring)	20
Oestrus detection	18
Poisoning detection	17
Refining fertiliser application	13
Genetic matching (male/female)	10

We have worked with numerous farmers to determine exactly how they would use these systems



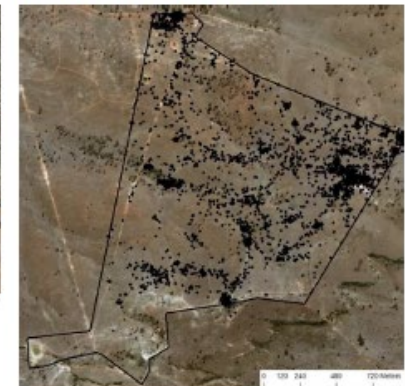
(a) "Rosebank" Longreach Qld



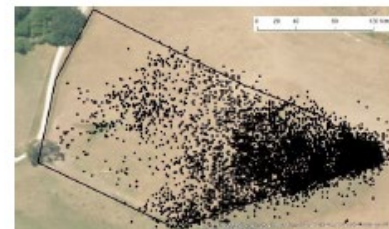
(b) "Shepherds Hill" Kingston SA



(c) "Warialda" Arthur River WA



(d) "Brindley Park" Qld



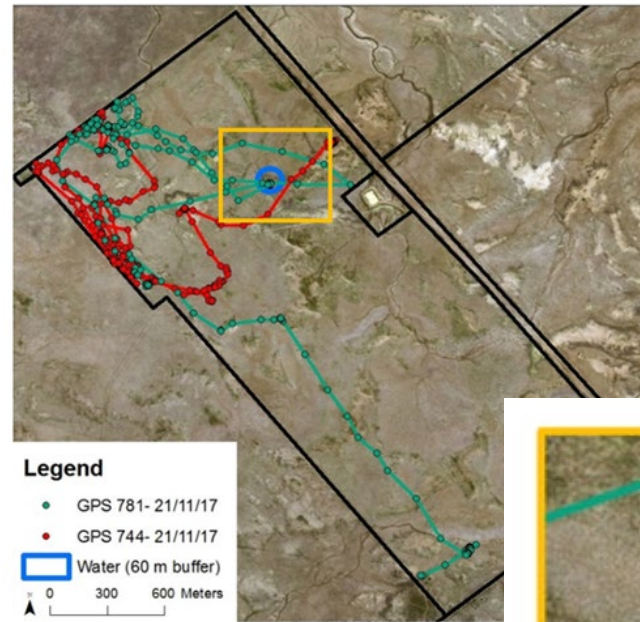
(e) "Stonyhurst" NZ



(f) Detecting Buffalo Fly - supply chain value - Landmark

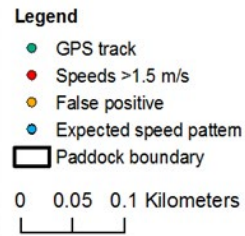
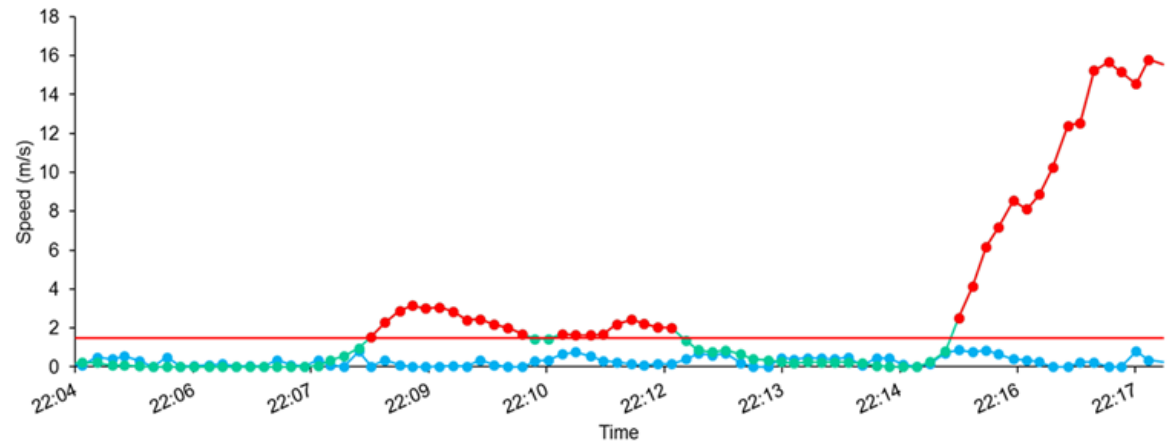
Are all animals getting to the water trough to have a drink?

- Two weaner lambs
- One gets a drink
- One walks right past!



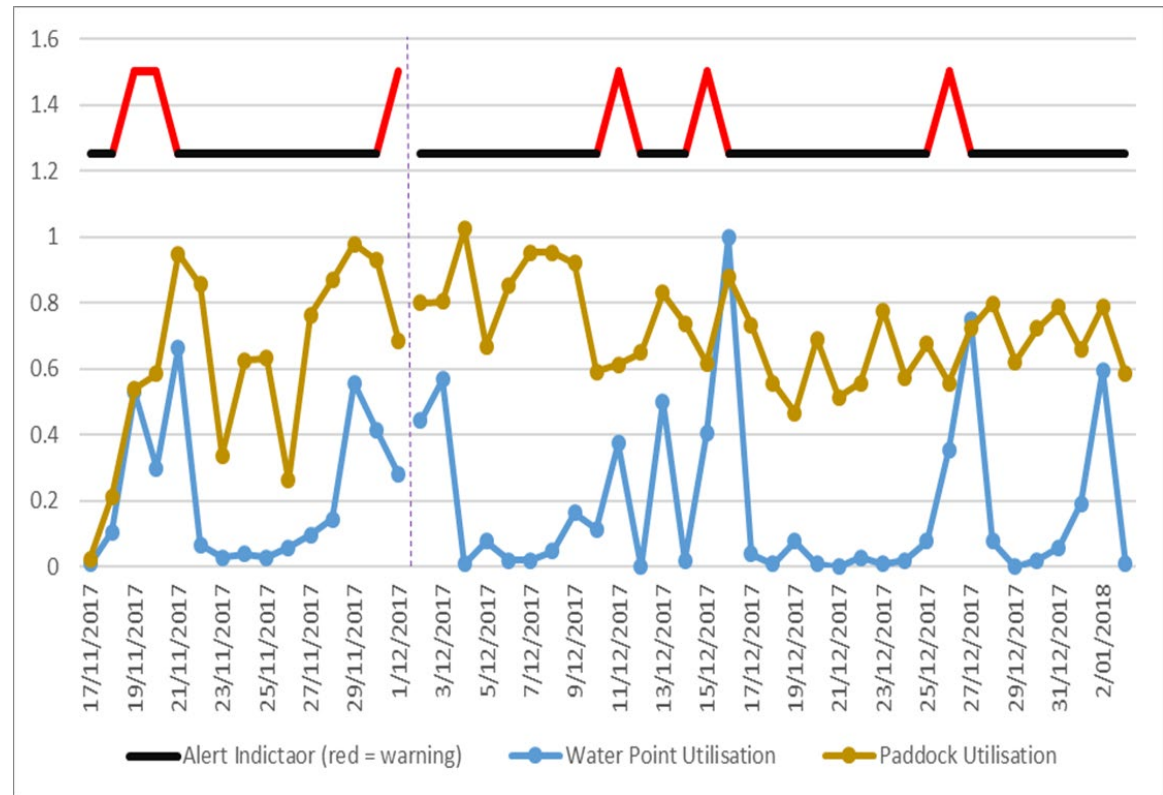
Andrew... *“This behaviour is really important in weaner sheep,”*
“Sometimes you can have the lead come in but by the time the tail end get there the lead are off and the last sheep turn around before they get a drink.”

Stealing your own sheep!



Detecting subclinical plant poisoning issues

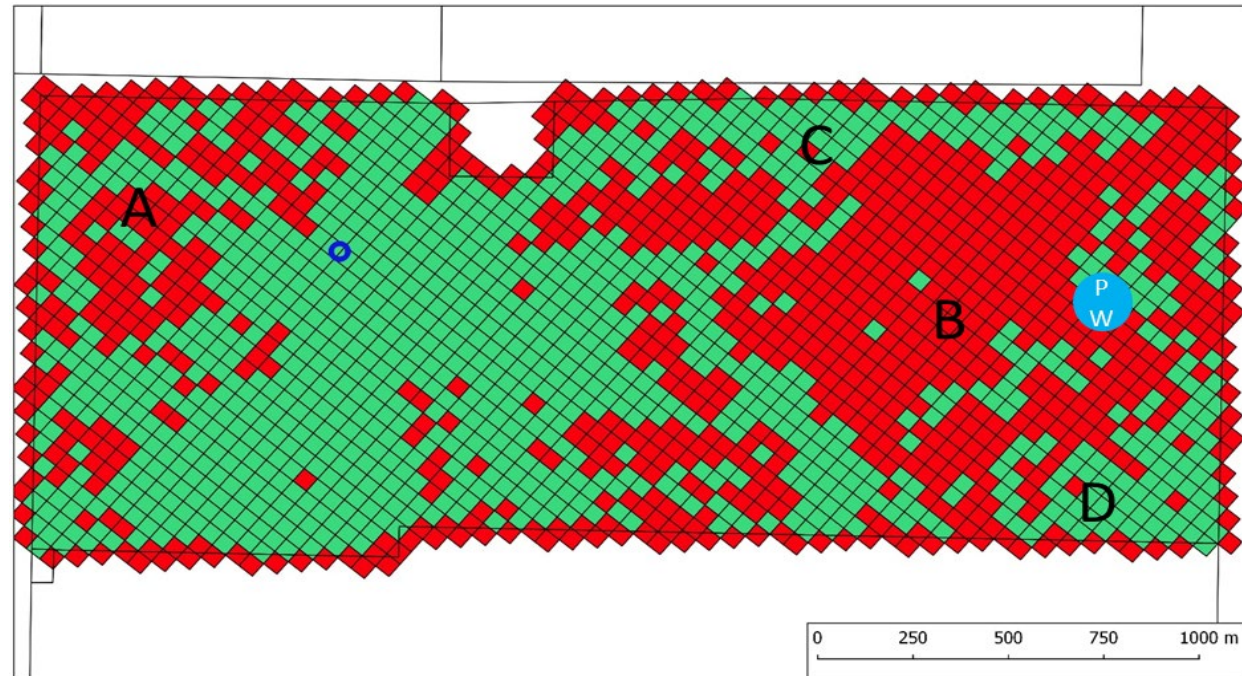
- Phalaris Toxicity (staggers)



Landscape utilisation on “Rosebank”



Rosebank Manager
“This GPS data would truthfully help design where we should be putting troughs”



Rosebank: Conways Paddock

Grazing activity recorded over all loggers

Legend

- Paddock boundary
- Water point

Paddock utilisation

- Underutilised
- Utilised



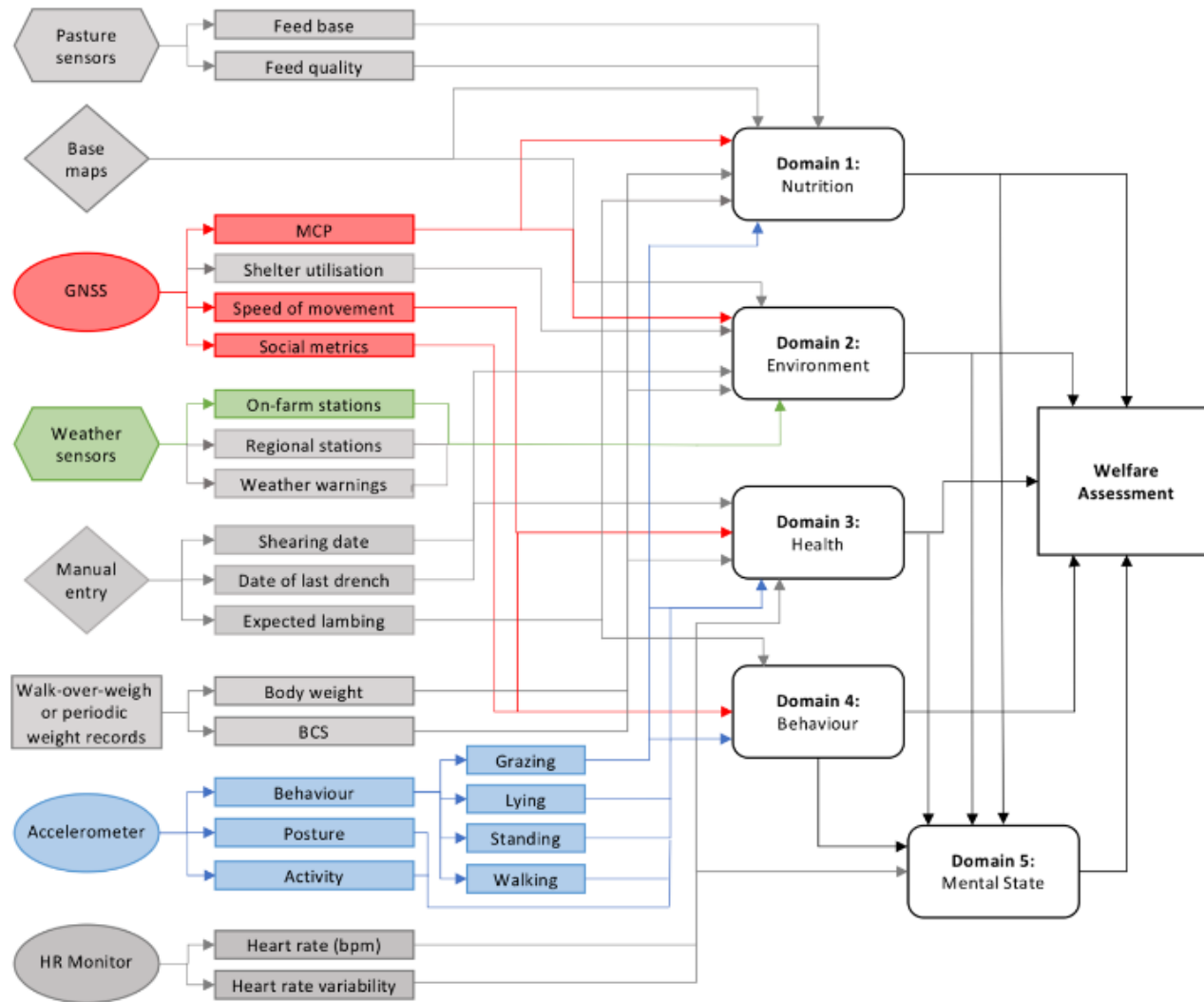
CQUni, March 2018

Beyond the farm gate? Into the value chain...

- Objective welfare measures?
- Objective sustainability measures?



Sensor based welfare detection

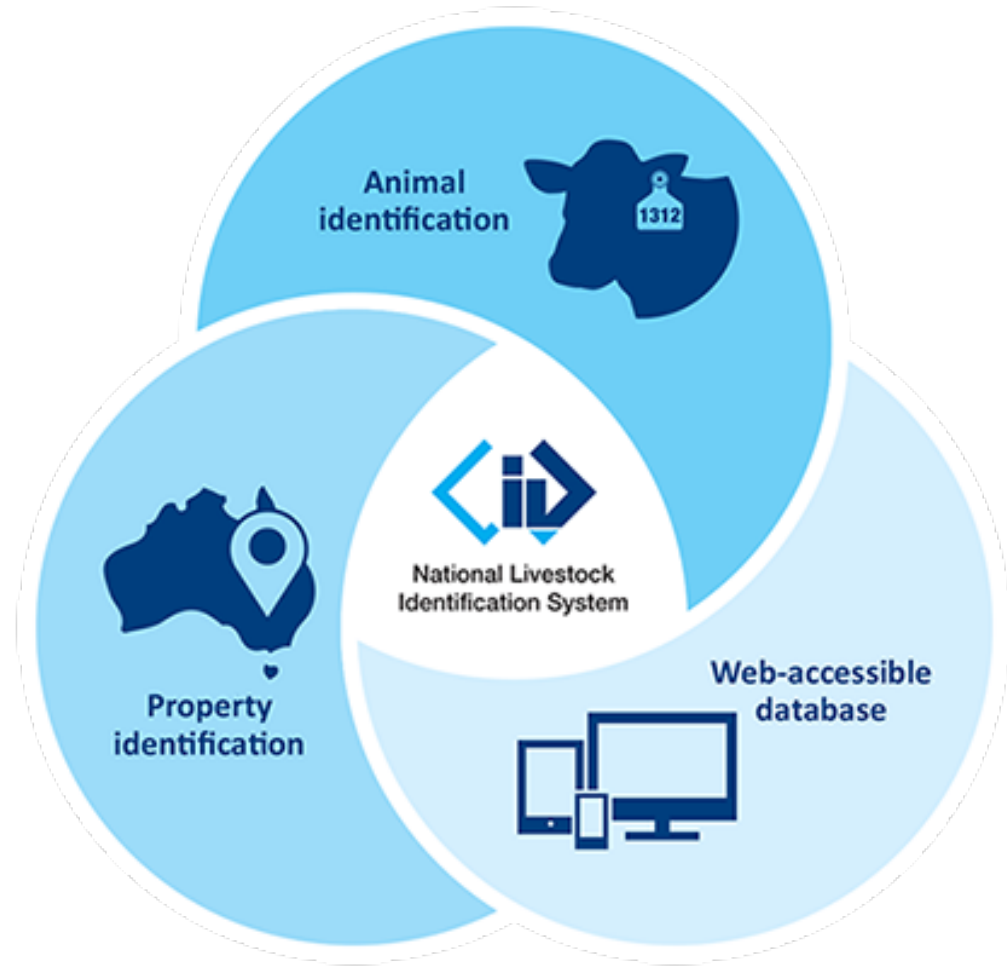


Fogarty, E. S., Swain, D. L., Cronin, G. M., & Trotter, M. (2019). **A systematic review of the potential uses of on-animal sensors to monitor the welfare of sheep evaluated using the Five Domains Model as a framework.** *Animal Welfare*, 28(4), 407-420.

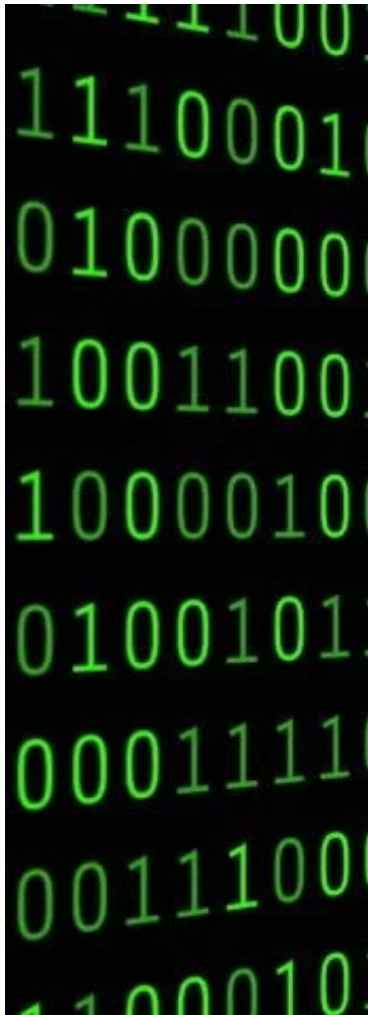
Government and regulators?



Integrity Systems



Our research focus: Behavioural algorithm development!



Warning!

There are cows calving. Please check the current alerts tab for further details.

Close

Apps

Map options:
 Base map Satellite

Resolution:
 Producer
 Researcher

Cow status:
 Pregnant
 Calving
 Calved
 Dead cow
 Dead calf
 Dead cow and calf
 Notifications off

Date for visualisation:
01 Oct 2018 10:00 pm

This project is funded by:

Good evening, Mark
You are at Belmont Research Station.
It is 10:00:00 PM on Monday 1 October 2018.

Animal overview

Cows that have calved: 0
Calving cows: 2
Cows yet to calve: 38
Cows with notifications off: 0

Herd data

Averaged across herd over last 24h
Activity index: 0.93
Distance travelled: 11 km
Speed: 0.21 km/hr
MCP: 23.65 ha
Weight: 488.435897435897 kg

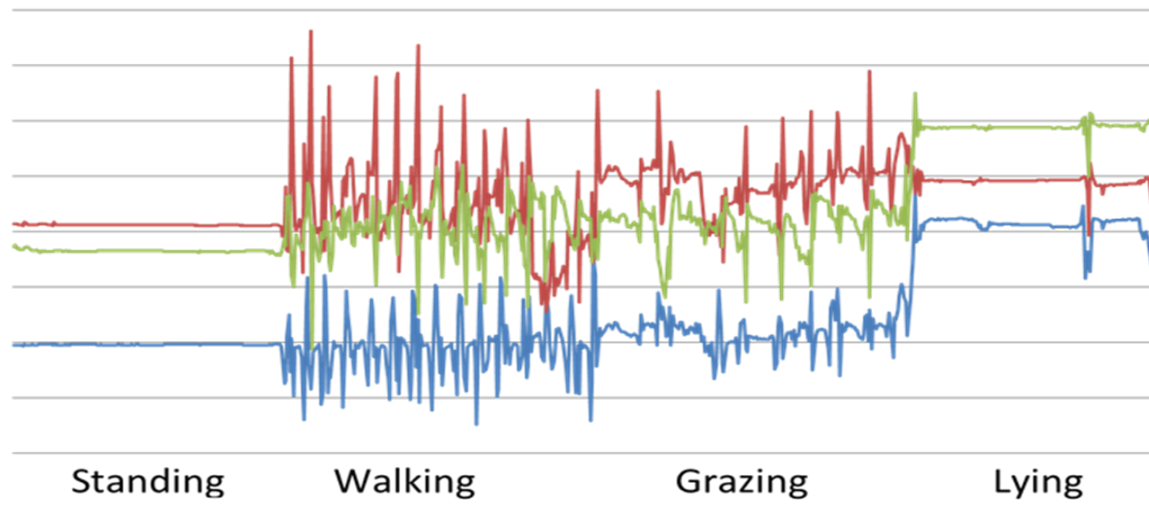
Weather data

Temperature: 20 °C
Precipitation: 0 mm
Humidity: 68 %
Temperature-humidity index: 66.208

Individual animal data Current alerts Animal notifications Animal notes

Download as csv Mark as calved

Basic behaviour modelling...



- Barwick, J, Lamb, DW, Dobos, R, Welch, M, Schneider, D, Trotter, M (2020) Identifying Sheep Activity from Tri-Axial Acceleration Signals Using a Moving Window Classification Model. *Remote Sensing* **12**, 646.
- Fogarty, ES, Swain, DL, Cronin, GM, Moraes, LE, Trotter, M (2020) Behaviour classification of extensively grazed sheep using machine learning. *Computers and Electronics in Agriculture* **169**, 105175.

Parturition/dystocia detection...



- Chang, AZ, Swain, DL, Trotter, MG (2020) Towards sensor-based **calving detection** in the rangelands: a systematic review of credible behavioral and physiological indicators. *Translational Animal Science* 4, txaa155.
- Fogarty, E, Swain, D, Cronin, G, Moraes, L, Trotter, M (2020a) Can accelerometer ear tags identify behavioral changes in **sheep** associated with **parturition**? *Animal Reproduction Science* 106345.
- Fogarty *et al.* (2020) Potential for autonomous **detection of lambing** using GNSS technology. *Animal Production Science*.
- Dobos, *et al.* (2015). Characterizing activities of free-ranging Merino ewes before, during and after **lambing** from GNSS data. *Small Ruminant Research*, 131, 12-16.
- Dobos, *et al.* (2014). The use of GNSS technology to identify **lambing behavior** in pregnant grazing Merino ewes. *Animal Production Science*, 54(10), 1722-1727.



Predation detection



- Manning, J, Fogarty, E, Trotter, M, Schneider, D, Thomson, P, Bush, R, Cronin, G (2014) A pilot study into the use of GNSS technology to quantify the behavioral responses of sheep during simulated dog predation events. *Animal Production Science* **54**, 1676-1681.



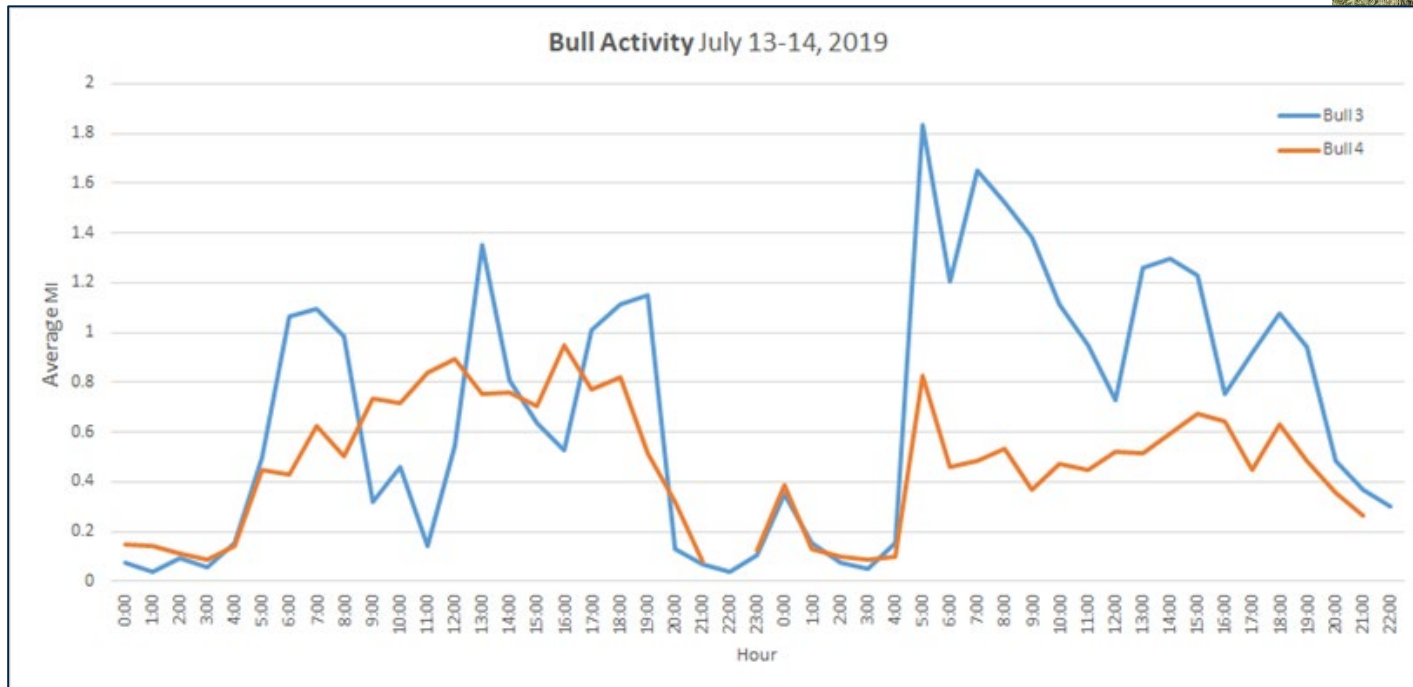
Disease detection



- Tobin, C, Bailey, DW, Trotter, MG, O'Connor, L (2020) Sensor based disease detection: A case study using accelerometers to recognize symptoms of **Bovine Ephemeral Fever**. *Computers and Electronics in Agriculture* **175**, 105605.
- Barwick, J, Lamb, D, Dobos, R, Schneider, D, Welch, M, Trotter, M (2018a) Predicting **lameness in sheep** activity using tri-axial acceleration signals. *Animals* **8**, 12.
- Falzon, G, Schneider, D, Trotter, M, Lamb, DW (2013) Correlating movement patterns of merino **sheep to faecal egg counts** using global positioning system tracking collars and functional data analysis. *Small Ruminant Research* **111**, 171-174.

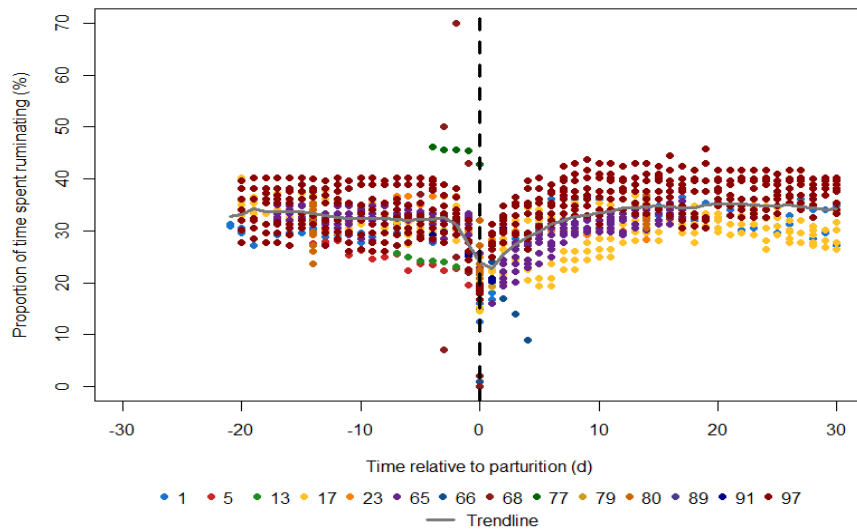
Bull mating activity and breakdown

- The Ohio State
- Dr Alvaro Garcia Guerra & Caleb Rykaczewski



How do we do this?

- Identify key behavioural indicators that might be measured using sensors
- Calving = rumination and isolation



Chang A.Z., Swain D.L., Trotter M.G. (2020)
Towards sensor-based calving detection in the rangelands: a systematic review of credible behavioural and physiological indicators.
Translational Animal Science, 4(3), txa155.



Select sensors



INDICATOR	SENSOR
Decrease in rumination	<ul style="list-style-type: none">• Accelerometer
Increase in isolation	<ul style="list-style-type: none">• GNSS• Proximity logger



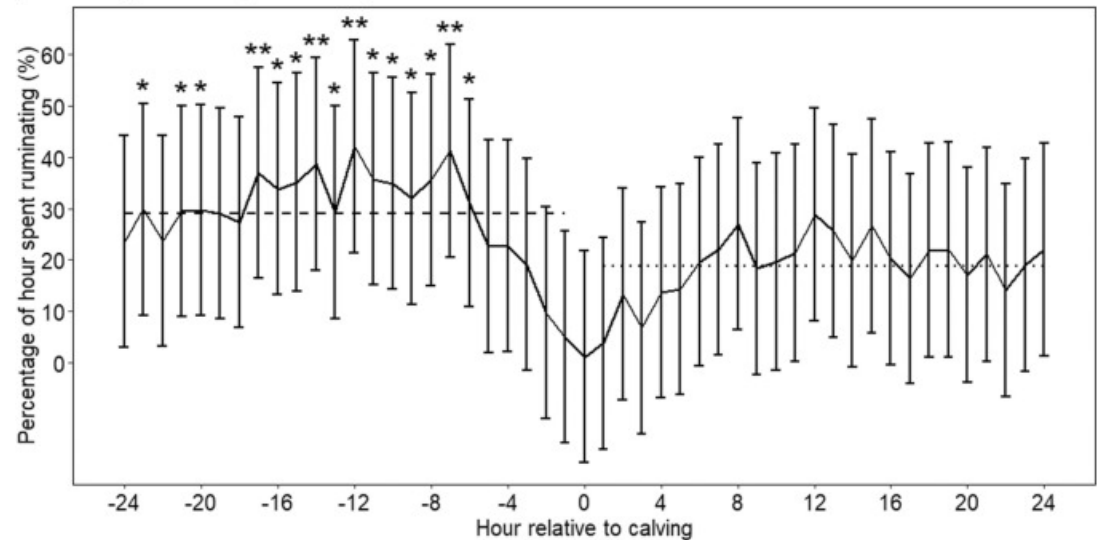
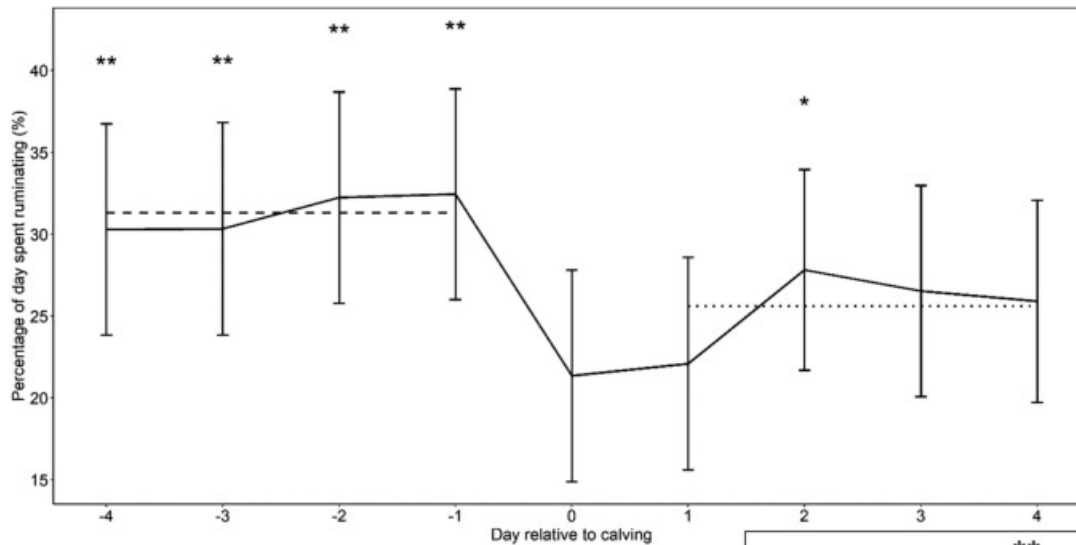
Rumination detection

- Accelerometer ear tags
- Data placed into various machine learning algorithms
- Individual animal rumination model using a classification and regression tree machine learning model = 98.4% accuracy



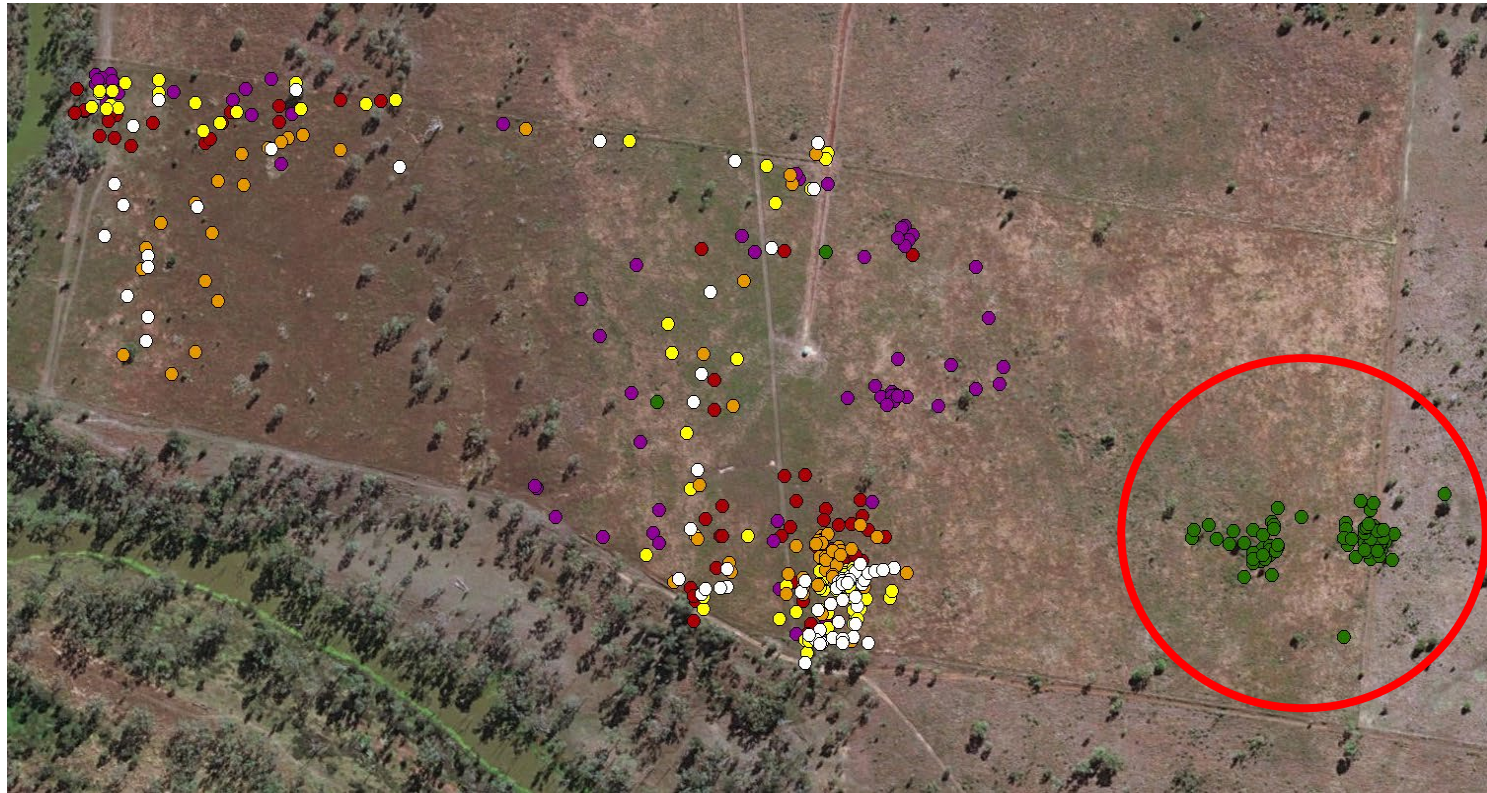
Chang A.Z., Fogarty E.S., Moraes L.E., Garcia-Guerra A., Swain D.L., Trotter M.G. (2022) **Detection of rumination in cattle using an accelerometer ear-tag: a comparison of analytical methods and individual animal and generic models.** *Computers and Electronics in Agriculture*, 192, 106595.

Rumination around calving

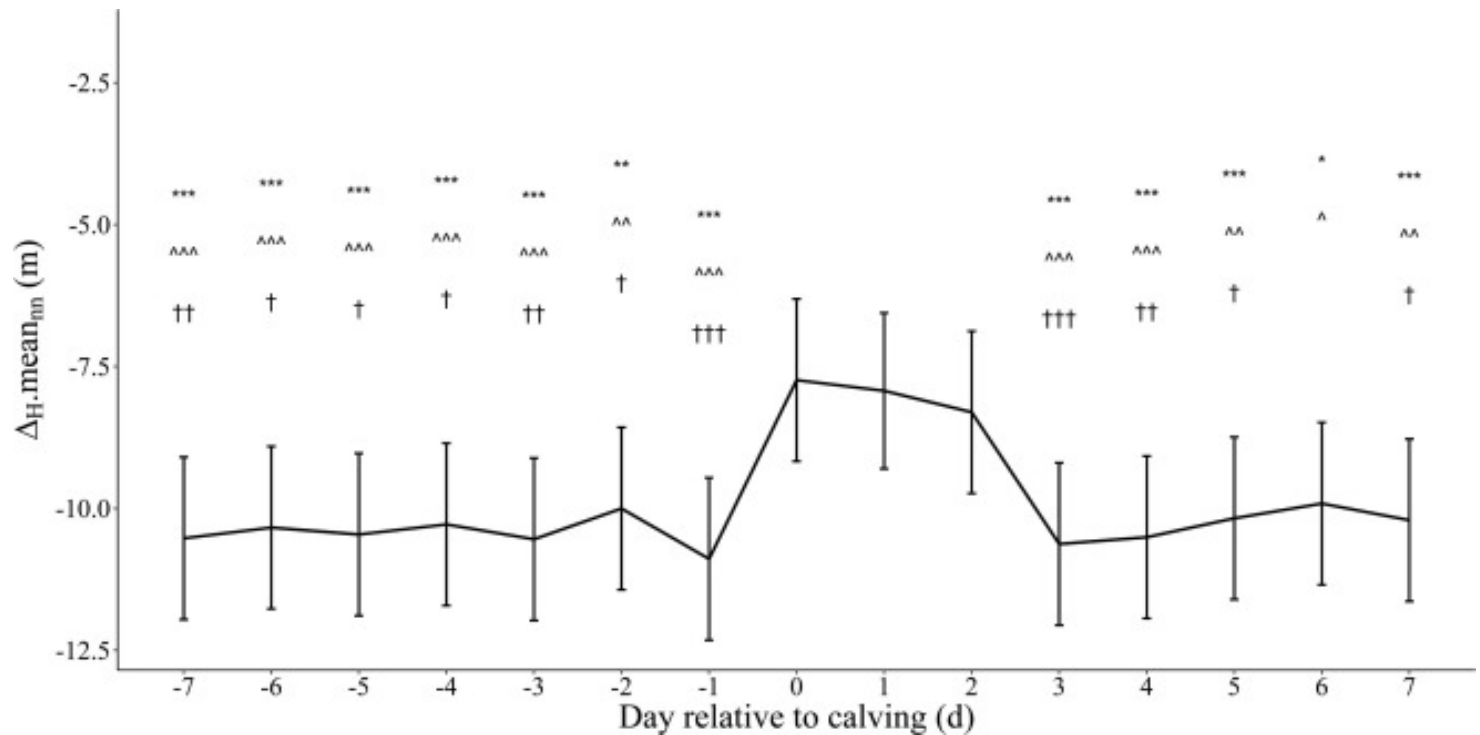


Isolation

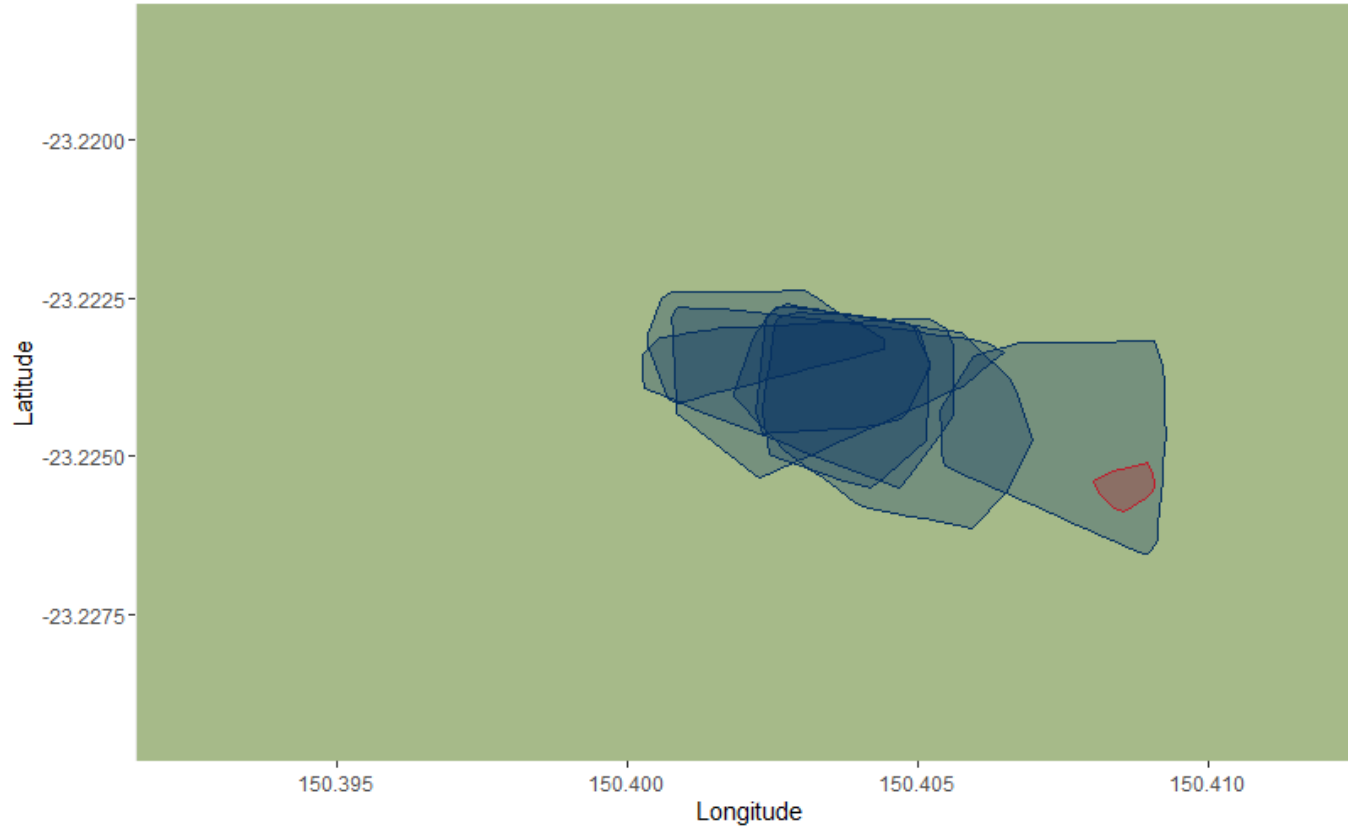
- GPS tracking...



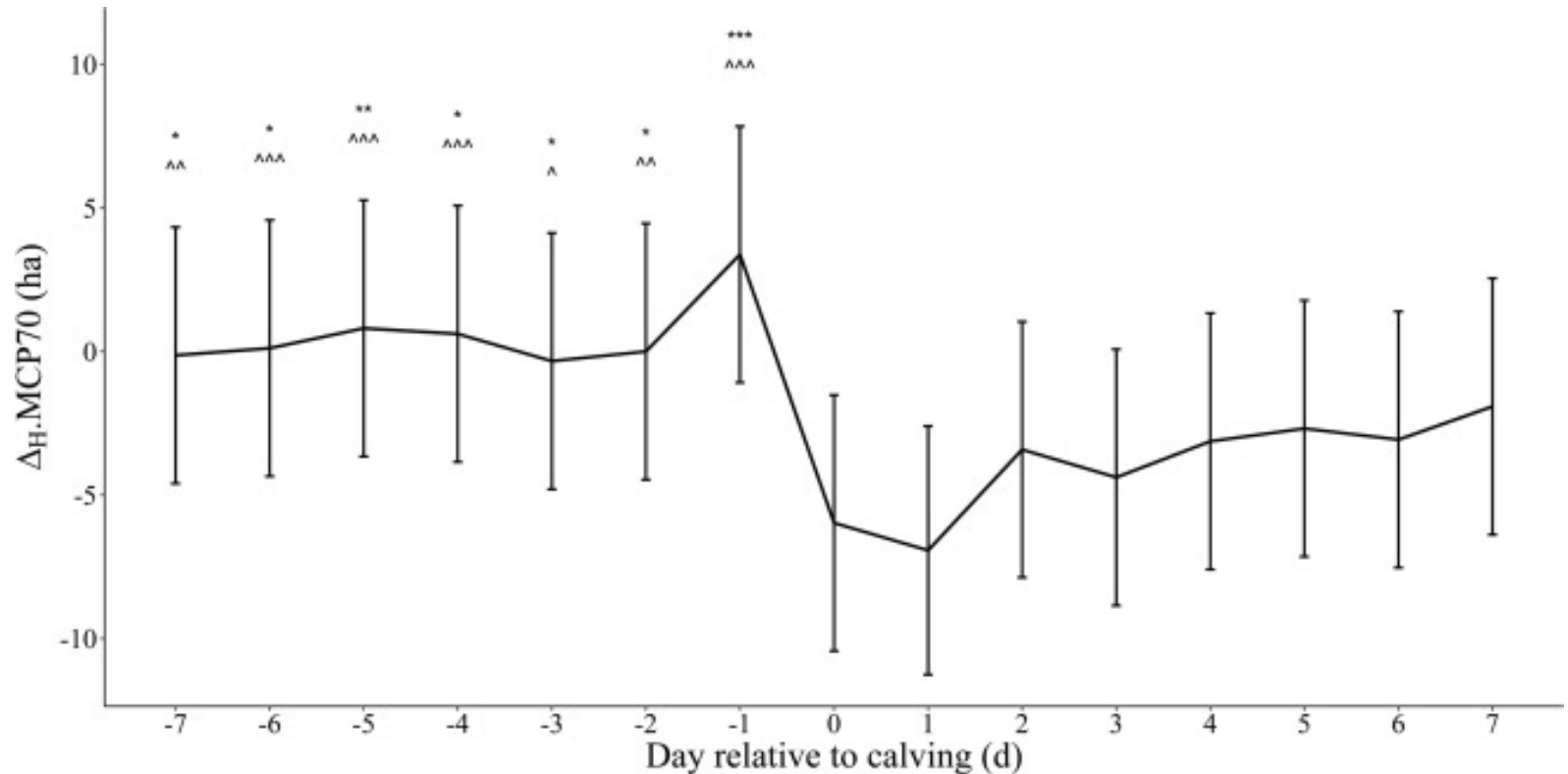
Nearest neighbour analysis



Constrained movement

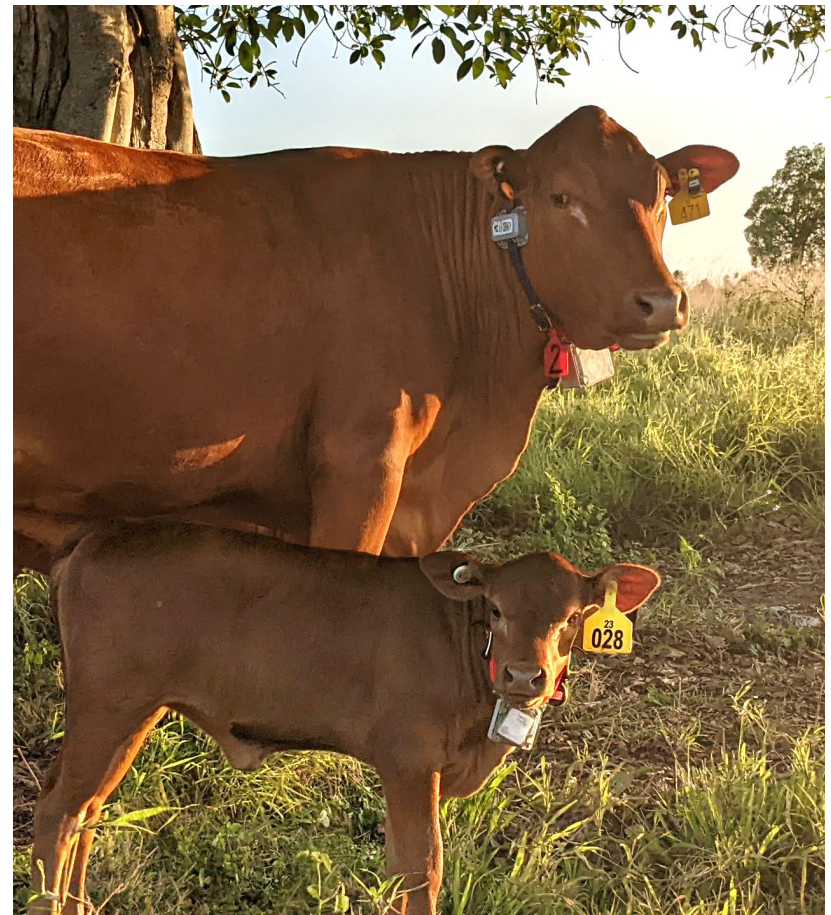


Minimum convex polygon...



Multi-sensor approach

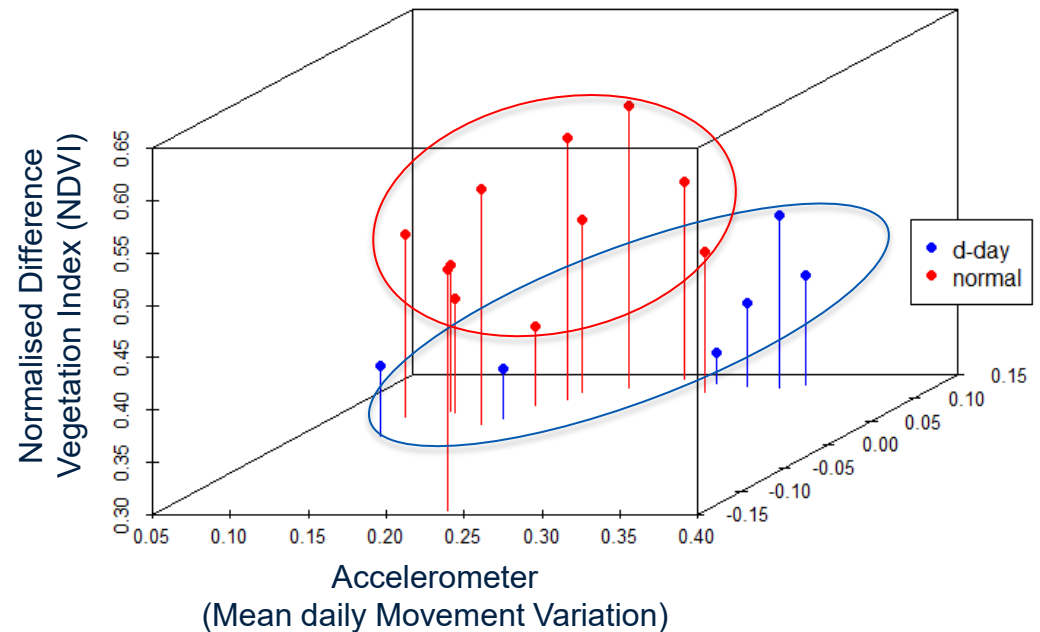
- Raw accelerometer ear tags, GNSS collars, walk-over-weigh, weather data, rumination model
- Mixed and matched sensor data



DATA SOURCE	ACCURACY	SENSITIVITY	SPECIFICITY
GNSS-rumination-weather	98.6%	88.9%	100%

The future - sensor integration

- Integrating vegetation sensing data with on-animal sensor data
- Improving spatial and temporal management of pastures and rangelands!



Where is all this going, what does the future look like?



- One day we will look back and wonder, how on earth did we manage livestock before we had this technology?
- Some of that might be good and some might not be so good!

Thanks!

